LXI Consortium

LXI Technical Overview

A presentation for implementers of LXI

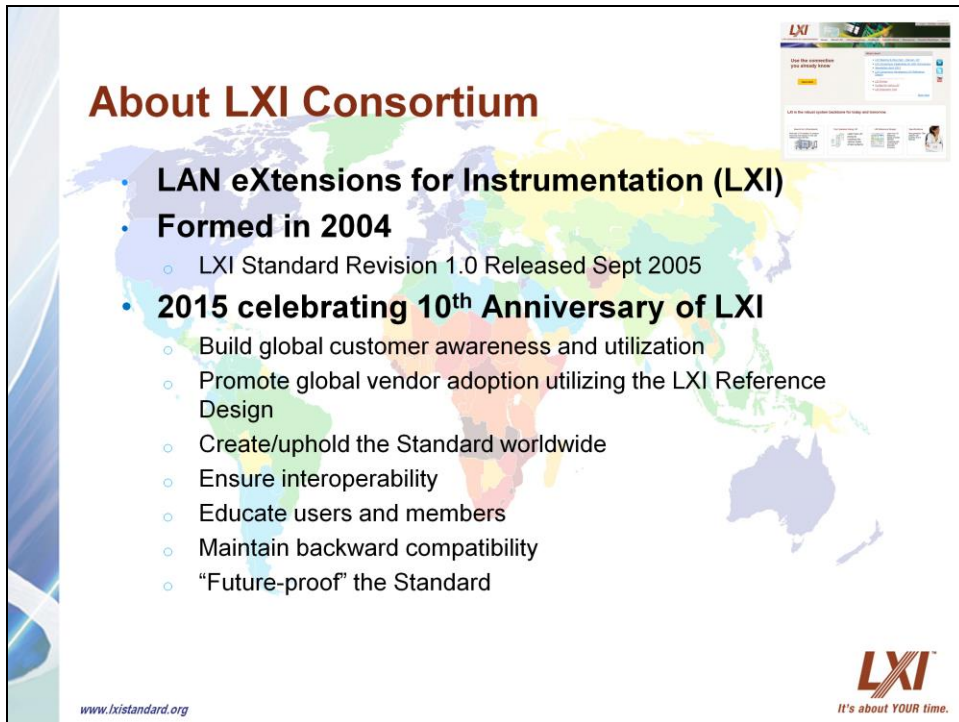*It's about YOUR time.*

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Welcome to the LXI Technical Overview. This presentation was designed to help members and potentially new members identify much of the Technology and effort involved in making an Ethernet Device LXI conformant.

This presentation is about 1 hour. Given so little time, this can only be an overview. However, content coverage and pointers to additional information should be more than adequate to give you a very good idea of what it takes to achieve LXI conformance.

Before getting into the technical aspects, let's review some facts about the LXI Consortium.

Every serious test interface makes bold claims about flexibility, scalability and performance—but only one extends the cost-effective power of LAN. LXI (LAN eXtensions for Instrumentation) is the robust system backbone for today and tomorrow, and it lets you easily connect the system you need: big or small, local or remote.

The top T&M companies have sponsored and developed this technology and have developed thousands of products from a diverse set of product families.

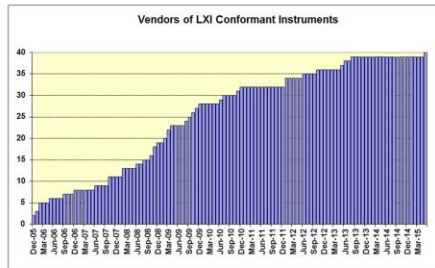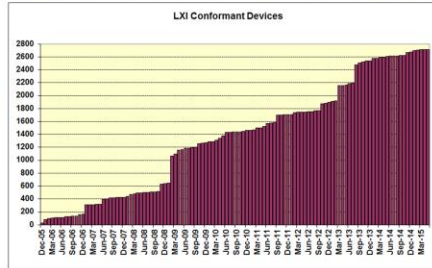The consortium is celebrating its 10th year of the LXI standard, and it is committed to the bulleted items above.

Ever since 2005, many companies have joined together to provide over 2600 LXI products, which includes products for virtually every type of test system. Just about every test and measurement product that was GPIB has added a LAN port and implemented the rigorous LXI requirements. In addition, many card-cage type products, including VXI, PXI, and AXIe have added LXI conformance, which gives a single LAN cable access to a wide variety of modules for building more compact test systems.

As indicated in the first slide, this presentation is designed to help project team members, testers, managers, etc. to better understand what technologies are involved to become LXI conformant. This is not a detailed presentation, but there is enough detail to bring you up to speed and know where to go for more information.

With LXI conformance, it does not matter who built the device, since they all behave the same when connected to LAN. This helps the customer in a big way.

First, we'll make sure you understand the basics of LXI, and then we'll move into exposing the various components, definitions, and processes involved.

The image in the upper right represents a collection of LAN equipped instruments. When becoming LXI conformant, those devices act just like a computer when connected to the LAN. Once connected, they can be discovered, serve up web pages, and can be programmed.

The Core Functionality is what makes all devices behave the same when connected to LAN. In addition, the LXI Standard provides many system-oriented capabilities that range from better communication to time awareness. These Extended Functions are optional, so not every LXI device has them. However, those that have implemented them work predictably with each other, according to strict enforcement by the LXI standard.

Don't be put off by the seemingly complex nature of becoming LXI conformant. The LXI Consortium has spent many years, resources, and funds in helping members to achieve conformance. You will be exposed to those resources in this presentation, such as the Conformance Test Suite, LXI Discovery Tool, and the recent addition of the LXI Reference Design. The Consortium consists of a lot of knowledge and experience with LAN-based instrumentation. The knowledge and resources can be easily tapped by becoming an LXI member.

What is LXI?

The power of Ethernet and Web

...inside Test Systems

Standard for LAN Instruments

...yielding these benefits to customers

- The ubiquitous nature of LAN
- Its high performance data transfers
- Low cost, readily available infrastructure
- Flexibility for wired or wireless communication
- Local and Remote access
- Abundance of multiple protocols for varied functionality
- Ability to embed Web servers within each instrument
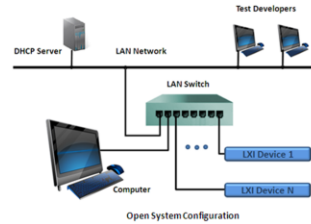
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LXI is the standard for LAN equipped instrumentation that helps reduce the time it takes to set up, configure, and debug test systems. LXI is an open, accessible standard based upon Ethernet that identifies specifications and solutions related to the functional test, measurement and data acquisition industries.

The bulleted items are self-explanatory.

LXI assures consistent LAN behavior

- **All LXI devices are tested on conformance**
  - Ensures interoperability – *testing of all rules*
  - Only T&M standard requiring conformance testing
  - COTS (**CO**nformance **T**est **S**uite) available for all LXI members
- **Conformance specs define general rules and agreements which vendors shall apply**
  - Permission to label their device with the LXI logo
  - Use the LXI logo in literature and other collateral mediums
- **Certified at LXI Plug Fests**
- **Certified by LXI test houses**
  - Rigol Technologies (China)
  - Wheelwright Enterprises (U.S.)
 - Keysight Böblingen (Germany)
  - TSEP - TSE Plazotta (Germany)

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LXI
It's about YOUR time.

It is important to recognize the rigor involved in becoming LXI conformant. Testing is performed by certified Test Houses.

The consortium does provide tools to help the vendors get ready for formal testing, since they are given the very test suite used by the Test Houses. It costs about $1000 to have a Test House certify your instrument through testing. However, you can also attend any one of the multiple LXI plug fests held around the United States, Germany, and China. When attending the plug fest, a Test House is always present to provide LXI testing. In this case, it is free to the LXI members, and they can get face-to-face interaction with the tester to discover and understand what aspects of their product are not passing.
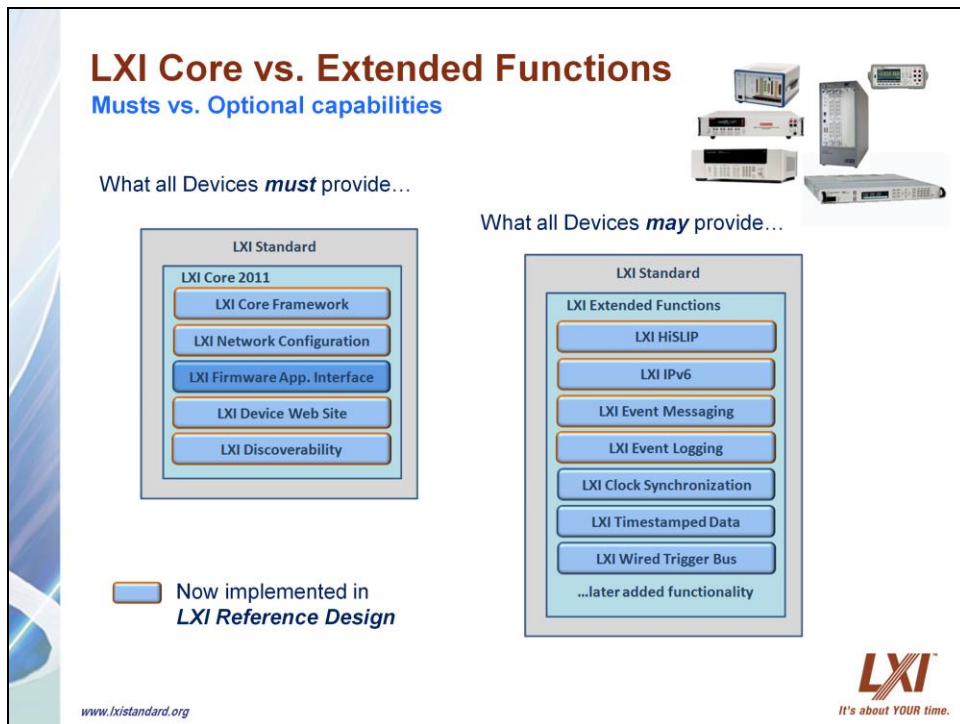
The LXI Standard consist of two general categories. The LXI Core 2011 (LXI 1.4) consists of functionality that is required by all LXI devices. This dictates how devices behave when connected to LAN, how they can be discovered, and how they must present LAN configuration status and control.

The Extended Functions cover optional capabilities available to LXI Devices. If implemented, they must conform to the various individual standards, so all products using those extended functions behave the same and can properly present that interface, status, and operation. This is a lot of work to implement. However, the LXI Consortium has created an LXI Reference Design to mitigate that complexity. Items highlighted in orange are provided for free to LXI members in the LXI Reference Design. You will note the Extended Functions for LXI HiSLIP, LXI IPv6, LXI Event Messaging, and LXI Event Logging are included in Reference Design.

More information on the LXI Reference Design can be found at:
http://www.lxistandard.org/Resources/Resources.aspx

Also, LXI Core and Extended Function specifications can be found at:
http://www.lxistandard.org/Specifications/Default.aspx

Here are some more details about the LXI Core functionality.

Of critical importance is the ability to connect the LXI device to any LAN subnet and acquire status information about the connection – IP address, hostname, etc. Once connected, the devices can be discovered using tools that understand the protocols used in LXI.

If a device cannot be discovered, it may be that the previous user of the device manually set its IP address to some value that does not work well in that subnet. No problem. The LAN Configuration Initialize (LCI – Rule 2.4.5) is either a button or menu item in a front panel display that forces the instrument back to a known state – acquiring an IP address from a DHCP server or obtaining an AutoIP address (or link-local addressing where the address is only available to the broadcast domain of the network segment).

Once you know the device's IP address, you can bring up its web pages for more status information and, in most cases, direct control of the device from a web page.

As you can see from the variety of images, an LXI device can take many shapes and forms. Some have elaborate displays and some none at all. Some are card cages with many modules that reveal themselves through the LAN interface both programmatically and via a web page.

Once connected to the LAN, the instrument can be discovered. At that point, you only need a web browser to view its information…

Here are two examples of web pages required by the LXI standard (Generally Section 9 of standard). Although vendors can choose colors, fonts, formatting, etc., they must provide certain information about the device and a certain level of control – to be able to re-configure network operation and to identify it among many other devices on the LAN.

This third feature is referred to as Device Identify. A menu button is presented on the Home page that when pressed, presents some form of blinking LED or message on the instrument in question. This is really helpful, especially if there are many instruments in the system with the same front panel look. Instruments without front panel displays make use of the LXI LAN Status indicator to provide LAN Fault, Normal Operation, and Device Identify with a multi-color LED (Rule 8.10)

Here are some examples of front panels – one with a display and another without.

The device with the display often presents its LAN information under some Utility or System menu. That is also where you will find the LCI or LAN Reset – the device LAN initialization (Rule 2.4.5)

If the instrument has acquired an IP address, status information will be indicated as "Good" or "Fail" on a display, and the display-less front panel will indicate success or failure with a Green or Red LED.

The LAN Reset should always put the device into a "Good" state, assuming it is connected to at least one other LAN device – which could be a direct connection to a computer or to a number of other devices using a LAN Switch or Router.

The discoverability of the LXI device is critical to its success in a test system. LXI devices have included multiple methods for discovery since the first release of the LXI Standard. Originally, a protocol called VXI-11 was required. VXI-11 is a somewhat intrusive method that asks the instrument to identify itself programmatically. If the device were busy at the time, it may not respond.

The standard was enhanced later by adding the XML Identification (Rule 10.2), which as you can see in the slide, is accessible from the IP address or hostname. Once you discover the IP address of the device, you can query the information directly from the XML Identification document. This does not require the instrument to programmatically respond, since it has to respond to LAN operations at any time.

LXI Revision 1.3 began enforcing a new protocol called mDNS (Rule 10.3). Used by printers for years, it is a service that constantly keeps track of other mDNS devices that connect or disconnect to the available LAN subnet. Discovery is almost instantaneous with this new approach, since cached information about every device on the subnet can be queried. The LXI Consortium created a tool that performs discovery, but companies such as NI and Keysight Technologies (and others) provide discovery tools in their IO Libraries for controlling instrumentation. These tools typically support all three methods of discovery.

Many companies provide the optional control of their products from a web page that is accessible from the Home page of the device.

These control pages can be monitor-only or they can actually allow full control of the instrument.

Test engineers rave about this capability, since it provides an easy method to debug their control programs by actually seeing the device change states. For devices that don't have front panel displays or for devices that are located maybe hundreds of feet from the programmer, this is invaluable.

With site-to-site virtual private networks, you can even control a device from around the world.
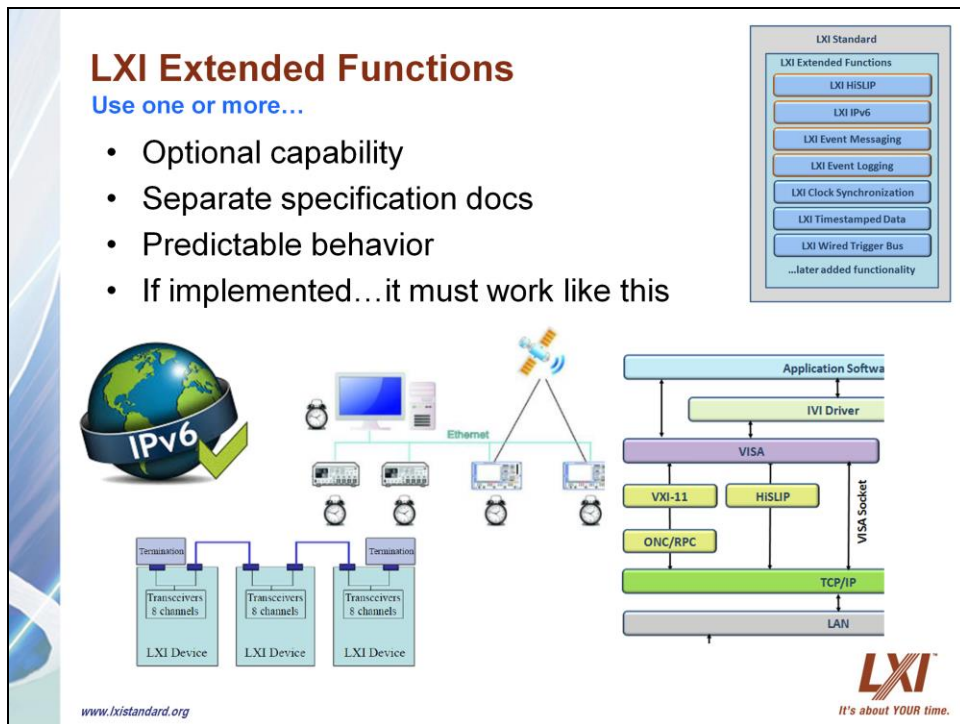
We mentioned earlier the Extended Functions are optional. LXI HiSLIP – a socket-based protocol that is highly recommended by the Consortium, since it provides Users with very low overhead, faster transactions between the computer and the LXI Device. IPv6 is another that is highly recommended, since it gives many benefits over the older IPv4 protocol…such as more efficient routing and packet processing, improved security, new services, etc.

The other functions provide such capabilities as time-awareness and time-stamping via time synchronization between all devices, such that device operations are coordinated based upon time-of-day rather than programming. Peer-to-peer events also provide control without the need of computer intervention. Even a hardware trigger subsystem between devices is fully specified.

Once again, the items highlighted in orange in the upper right image indicate which of these Extended Functions are supported in the LXI Reference Design.

Overview of Protocols
Standard LXI Device Ports, Protocols, and Services

Protocol/Service	Port	Base Protocol	Notes
mDNS	5353	UDP/TCP	Zero-config protocol for <hostname>.local address resolution; service discovery; Multicast 224.0.0251, FF02::FB
Http	80	TCP	Instrument web pages
ICMPv4		ICMP	Typically enables echo request/respond for ping
ICMPv6		ICMP	Optional - Typically enables echo request/respond for ping, also SLAAC for IPv6 addresses, RDDNS
Arp		Arp	Used to confirm address assignments
DHCPv4	67/68	UDP/TCP	IPv4 address assignment, DNS Server, Dynamic DNS, Gateway
DHCPv6	546/547	UDP/TCP	Optional IPv6 address assignment, DNSv6 Server, IPv6 Gateway
DNS	53	UDP	Naming service
Telnet	23	TCP	Bidirectional interactive text-oriented communication.

Optional refers to Extended Functions
✔ Included in *LXI Reference Design*

LXI Standard

LXI Core 2011
- LXI Core Framework
- LXI Network Configuration
- LXI Firmware App. Interface
- LXI Device Web Site
- LXI Discoverability

LXI Standard

LXI Extended Functions
- LXI HiSLIP
- LXI IPv6
- LXI Event Messaging
- LXI Event Logging
- LXI Clock Synchronization
- LXI Timestamped Data
- LXI Wired Trigger Bus
- ...later added functionality

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LXI It's about YOUR time.

There are many protocols associated with LAN, and here are the ones required for various aspects of the LXI Standard. This is a lot to learn, but the good news is the LXI Reference Design provides most of that capability. Those protocols supported by the LXI Reference Design are indicated with check marks.

The current LXI Specification can be found at:
http://www.lxistandard.org/Specifications/Specifications.aspx

The Appendix D of the LXI Device Specification gives descriptions of these protocols.

Overview of Protocols
LXI Device-specific Ports, Protocols, and Services

LXI Device-specific Ports, Protocols, and Services			
Protocol/Service	Port	Base Protocol	Notes
HiSLIP	4880	TCP	Optional instrument control protocol
VXI-11	111	TCP	Builds upon Sun-RPC and port-mapper.
Scpi-raw	5025	TCP	Optional instrument control protocol
Scpi-telnet	5024	TCP	Optional instrument control protocol over Telnet
LXI-eventsvc	5044	UDP/ TCP	Optional LXI Event support for instrument triggering; multicast 224.0.23.159, FF02::138
Ptp-event	319	UDP/ TCP	Optional LXI Profile IEEE 1588 Precision Time Protocol; multicast 224.0.1.129, FF02::181
Ptp-general	320	UDP/ TCP	Optional LXI Profile IEEE 1588 Precision Time Protocol; multicast 224.0.1.129, FF02::181

Optional refers to Extended Functions
✔ Included in *LXI Reference Design*
✳ LXI release 1.5 will reduce VXI-11 to Recommended

LXI Standard
LXI Core 2011
- LXI Core Framework
- LXI Network Configuration
- LXI Firmware App. Interface
- LXI Device Web Site
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LXI Standard
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- LXI IPv6
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Here are even more protocols as part of the LXI Standard, but these are all related to Extended Functions. Once again, the LXI Reference Design provides key protocols used by most devices.

With the release of LXI 1.5 in the latter part of 2015, VXI-11 will no longer be a requirement, although it is still recommended. That is why it is not included in the LXI Reference Design, which is also formally releasing later in 2015. Even so, VXI-11 discovery is covered in the LXI Discovery Tool, of which the source code is available to LXI members.

The current LXI Specification can be found at:
http://www.lxistandard.org/Specifications/Specifications.aspx

The Appendix D of the LXI Device Specification gives descriptions of these protocols.

The LXI Conformance process is detailed in this document. It includes all the information you should need to acquire first-time certification of an LXI Device. It also includes information on what to do if you are updating products that have already been certified or adding follow-on products that all utilize the same computer-LAN infrastructure.

This is really important to understand. For example, say a device is certified by a Test House as LXI conformant, but months later, that device changes its operating system from Windows XP to Windows 7, LAN hardware/driver, adds Extended Functions, etc. Such changes would require re-certification by a Test House to make sure the device is still conformant. In those cases where the product is truly a follow-on to the same infrastructure, where maybe the measurement hardware specifications are slightly different due to performance, the vendor need only re-run the LXI Conformance Test suite themselves to verify the product still passes all the requirements…and then submit the test suite output and conformance technical justification form to the consortium for official conformance.
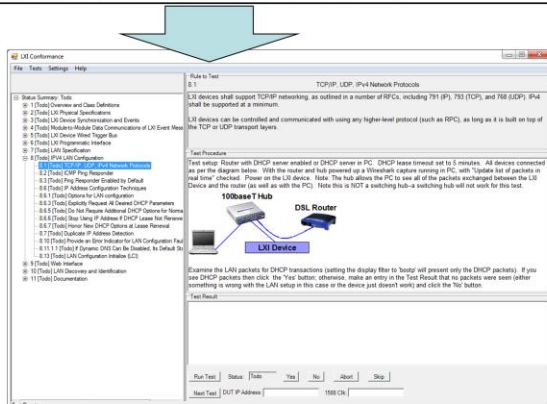
Here is a link to this document:
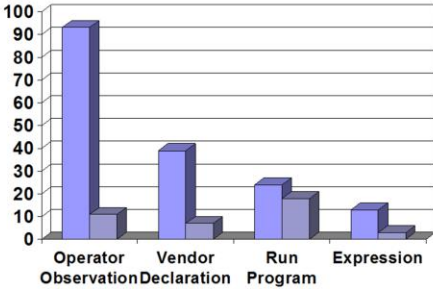http://www.lxistandard.org/Specifications/Specifications.aspx

The many, many pages of rules and recommendations the LXI Standard are compressed into the LXI Conformance Test Suite, which is run by a Test House during LXI conformance testing. This test suite is also available to LXI members.

Let's quickly walk through the key aspects of this test suite.

The test suite can be downloaded as a zip file from the LXI website after becoming an LXI member:
http://www.lxistandard.org/login.aspx?ReturnUrl=%2fmembers%2fConformance+Co mmittee

The test suite components are listed to the right. You will note there are a lot of Perl script (pl extensions) and executable files that constitute the automated portions of the test suite. However, the bulk of the test is actually interactive with the operator. The operator would be you when running the test, but it is the Test House operator during the certification process. The distribution of tests is outlined in the graph, where the Operator Observation and Vendor Declaration make up the majority of test. Expression represents a combination of rules to establish a macro representation of the test.

The file help.html describes what is necessary to setup the hardware and software for running the test suite.

LXI Conformance Test Suite
Software pieces

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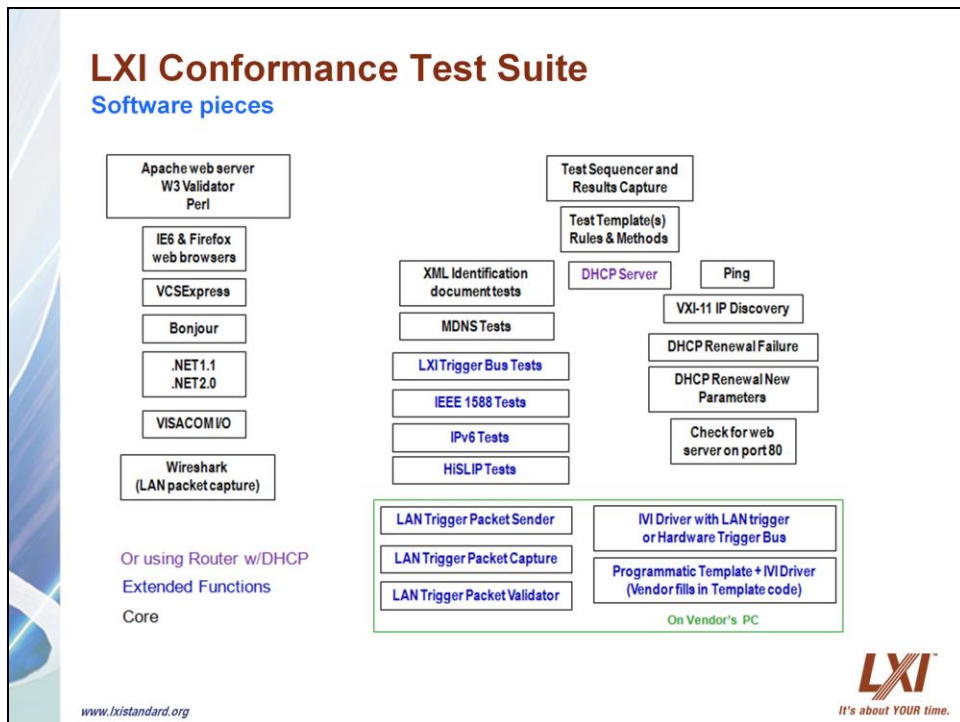
Here is a block diagram view of the test suite software components. The items on the left are those required for the testing computer, and the aforementioned help.html file explains how to install those items.

The items to the right indicate what is "Core" vs. Extended Functions (in blue). The DHCP Server is an integral part of the testing, and this service can be provided by an external Router or as a DHCP server installed on the computer. Lynn Wheelwright, of Wheelwright Enterprises, has written this test suite, and he prefers to install the supplied DHCP server on his laptop. This is a convenience for traveling with less hardware, but many prefer to utilize the external hardware router and hub detailed in the next slide.

Note that the vendor should be present for testing of certain LXI Extended Functions noted in the green bordered box on the bottom.

It is not necessary to walk through each of these setup steps, but it does indicate what needs to be supplied. Lynn has provided recommended configurations of the computer and router, such that test operations can be controlled.

The Hub is more difficult to obtain now days, but used hubs are readily available on eBay. The hub permits the PC to see all the traffic going on between the Router and the LXI Device, which would be blocked when using a standard LAN Switch. Wireshark is recommended in the test suite to capture LAN traffic. Familiarity with this tool is critical to properly identify the correct packets and sequence of packets. You do not need comprehensive understanding, but you need the basics. YouTube and other resources are a rich source of acquiring this understanding, but Lynn has also included tips in the Test Procedure sections of those tests relying upon Wireshark.

The DHCP Router supplies IP addresses to connected devices. However, when you disconnect it from the Hub, the computer and LXI Device drop into the AutoIP mode. Lots of the Rules are exercised by connecting and disconnecting the cables between these devices…with the subsequent LAN traffic monitored by Wireshark and the LXI Device LAN Status Indicator.

This slide helps you understand the control aspects of the test. The LXI Device Data is what specifies what is being tested…and this also directs the test suite sequence. After specifying what type of device is to be tested, you would start off with the Vendor Declarations, which represent a lot of typical questions only the vendor would know specifically about their product…IEC rack standards, shielding, etc. It also includes general questions such as support for mDNS, IVI Driver, etc.

Sometimes tests fail during the procedure, after you have corrected the situation, you can re-load the test information from a saved file and re-run that specific test…thus continuing with the test rather that starting over.
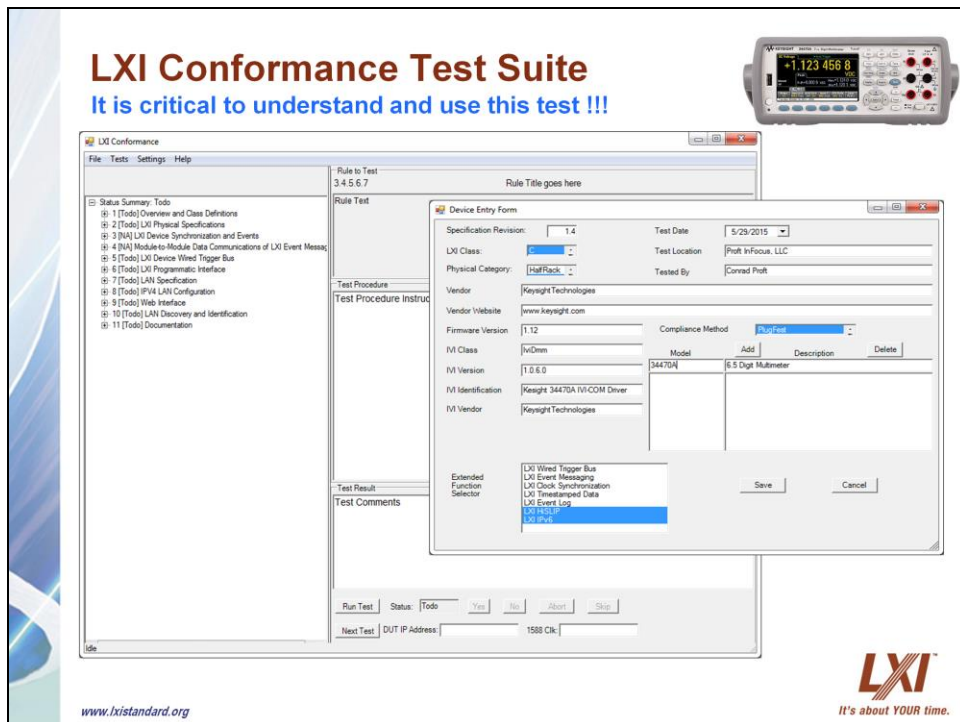
Understanding how to use this test is absolutely critical. Many gloss over the importance of the interactions with the operator during this test. As we shall see more closely in the next slide, each rule being tested is represented along with a Test Procedure. The operator interactive tests rely upon the operator correctly assessing the information presented on web pages, Wireshark, LAN Status Indicator, the W3C html Validator, etc.

Here is an example of the LXI Device Data. Note you must select the Extended Functions for testing. If you don't include them, the test suite will determine your product actually is declaring they are present, and the test will fail simply for that reason.
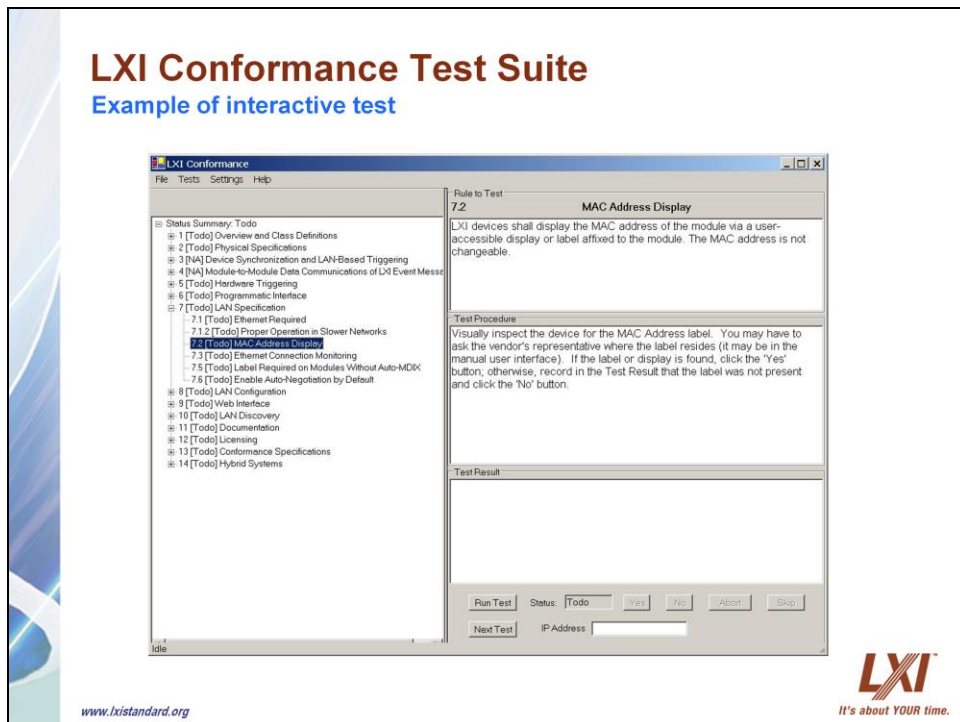
A long list of tests are represented as collapsed or expanded. There is a lot of jumping around sometimes from one section/rule to the next, which represents the importance of multiple rules for macro capability. For example, if you specify you do not support such-in-such in a question, then the test will not proceed to another portion of the test, and a failure is usually the result.

The general format is to present the formal LXI rule in the top box, and the test procedure is detailed in the center box. The test procedure is what the operator follows. For some tests, this is automated the pass or fail is conducted automatically by the test. For operator oriented tests, there will be some observed result where the User is required to answer Yes, No, etc. The lower box is typically where you would take notes during the test. These are later captured and output to the test results file used to summarize the results of the overall test.

The **Run Test** allows you to pick a test on the left and "Run" it, where the Yes, No, or automated result occurs. **Next Test** allows you to jump ahead. The IP address at the bottom is usually discovered by the test suite, but when re-running a test in the middle of the test suite, you often have to manually enter the IP address of the device.

The next two slides cover additional resource created and maintained by the LXI Consortium.

The LXI Discovery Tool provides a simple method to discover LXI Devices on a subnet. It was developed by and for LXI members. LXI Members have access to the source code and project, so it is beneficial as a learning tool for those interested in LXI Device discovery.

As noted earlier, LXI 1.5 will reduce VXI-11 to Recommended, and the discovery will not be included in the LXI Reference Design. However, with the source provided in this tool, you can learn how this all works.

LXI Reference Design Overview
LXI Member Benefits

- Available to all LXI Members
- Lower barriers to LXI entry
- Reduces design cost
- Compatible with common tools/platforms
- Makes it more likely to pass the LXI Conformance test the first time
- Use of LXI logo gains more market acceptance
- Fewer support issues since members can use the support documents created by the LXI Consortium
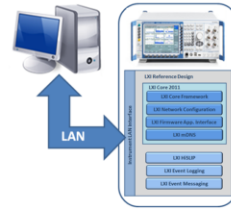
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We've mentioned the LXI Reference Design many times during this presentation. Here are the specifics in the next couple slides.

This tool really provides a service to new members of the LXI Consortium, since much of the heavy lifting of various protocols is provided free to members.

The listed benefits are fairly evident.

LXI Reference Design Overview
Provides the infrastructure for LXI support
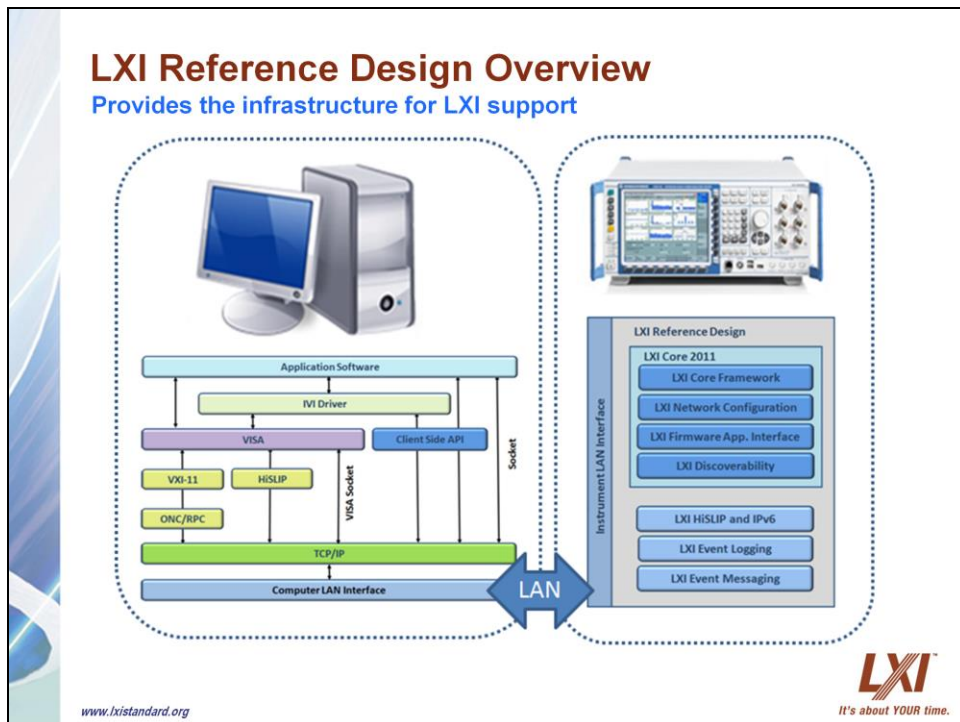
Looking a little closer, you will note that there are a number of standards between the computer and LXI Device represented. The computer gains access to the LXI Device via LAN protocols, such as Web (http). However, most of the devices are programmed within a test system, and this requires a variety of support from vendor supplied libraries or the earlier mentioned IO Libraries supplied by such companies as National Instruments and Keysight Technologies.

The various software layers ultimately connect to the LAN and then to the LXI Reference Design provided implementation, which ties the functionality of the device to the computer. The LXI Reference Design represents a lot of effort and value to LXI members.

You can obtain more information about the evolving LXI Reference Design in the Resources section on the LXI Consortium website:

http://www.lxistandard.org/Resources/Resources.aspx#tabs-5

Key Points developing LXI Device
Typical Team Experience

- Expertise in C, C#, or C++ Embedded Design
- Expertise in hardware development/programming
- Expertise in platform operating system

But…

- Low expertise in network Development
- Low expertise with HTML, Java, Active Server Pages
- Low expertise in developing IVI Driver

Whoa…how can I build up my expertise?

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A typical project team consists of a lot of good engineers, who are experts in their company's product domains…but they typically don't have much expertise in network protocols. Obtaining such expertise is important, but the time to acquire that expertise can be considerable.

"Who are you going to call…?"

Key Points developing LXI Device
LXI Consortium to the rescue

- Become a Member of LXI
- Pick up the *LXI Reference Design* as a member
  - Supports a range of operating systems with OS/HW abstraction layer
  - Build with *LXI Reference Design* source code
  - Implement instrument firmware as expected by *LXI Reference Design*
  - TSEP Consulting on LXI Reference Design
- Other LXI Consortium Resources:
  - LXI member forum
  - *LXI Reference Design* documents
  - Join an LXI Working Group

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Becoming an LXI Member and picking up the LXI Reference Design provides short-term solutions for that networking knowledge and gives certain team members time to acquire additional insight. Expertise in understanding the LXI Conformance Test Suite is still required, but understanding what should happen vs. how to make it happen is made considerably easier with the LXI Reference Design.

In addition, TSEP, the company developing the LXI Reference Design, will be providing support to implement their design. Your engineers will provide the expertise to your computer engine architecture and OS, and TSEP will help you understand how to tie it all together.

And, joining various working groups, forums, and attending Plug Fests is an ideal method to gain help from the most experienced vendors in the industry.

Key Points developing LXI Device
IVI Driver Development

- Make It Yourself using tool
  - Pacific Mindworks Nimbus – IVI Com or IVI-C
  - National Instruments CVI – IVI –C
  - Vektrex VIVID IVI Driver Development tool
  - Testing can be ½ of the effort.
- Subcontract
  - Pacific Mindworks
  - Vektrex Electronic Systems
  - National Instruments

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The IVI Driver is part of the LXI Conformance process, and this can be difficult to implement as well. However, there are tools, consultants, and driver providers available to assist you.

This driver pulls together the programming consistency for the Users of LXI Devices…such that their overall experience in using LXI Device is enhanced.

Don't underestimate the testing time it takes to make sure your IVI Driver works properly and is complete enough to provide adequate coverage of the product for your customers. Suppliers of drivers will need a complete requirements document as well. They will usually test to those requirements from a unit-test standpoint, but it is your responsibility to make sure the product functions as expected to achieve proper measurement operation.

The IVI Driver is NOT tested by the Test House for Core capabilities; however, for Extended Functions such as LXI Timestamping, LXI Event Logs, etc., the Test House will need the driver as part of a project supplied by the vendor to verify certain operations. This is probably best done at one of the multiple Plug Fests provided by the LXI Consortium each year.

Key Points developing LXI Device
LXI Regression and Conformance Testing

- Testing is a significant portion of development
  - Develop LXI Test Suite expertise
  - Much time will be wasted by not using and understanding LXI Conformance Test Suite
  - LXI Testing should be integral part of firmware testing
  - Each release candidate needs to run LXI Test Suite
  - Upgrades to OS, LAN Drivers requires formal LXI Conformance Testing by Test House

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Speaking of testing...we've mentioned the importance of the LXI Conformance Test Suite in much of this presentation. It is really important to have someone designated to run this test prior to applying for LXI conformance. You will save a lot of time and expense by catching problems before they are discovered by the Test House.

Test early and test often should be your guiding principle. Do not rely upon the automated portions of the LXI COTS test. Many important aspects of the test involve operator observance of what is happening with web pages, mDNS discovery via Bonjour, Wireshark packets, etc.

And, as indicated earlier, LXI conformance is an on-going process. You cannot simply get tested once and not re-verify or re-test when making significant changes to the LXI Device's OS or LAN driver.

Want to know more?...go to the web site.

Some areas are exclusive to LXI members, usually related to some of the tools and resources. To learn more about LXI, select the About LXI or Learn More, and you will be directed to a wealth of insight into various uses and operation of LXI Devices…from Getting Started to Maximizing Performance of LXI-based Test Systems.

Also, take a look at all of the LXI Devices on the Products link. The Specifications will give you access to the current LXI Standard. Resources provides a plethora of information from various vendors, magazine articles, presentations, papers, etc.

Visit web site

http://www.lxistandard.org/
More Information on LXI

Contact Bob Helsel, Executive Director or any other board member

http://www.lxistandard.org/ContactUs.aspx